PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO FUEL INJECTION SYSTEMS FOR ENGINES

(71) We, THE PLESSEY COMPANY LIMITED, a British Company of 2/60 Vicarage Lane, Ilford, Essex, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a fuel-injection system for an engine and is a modification of or improvement in the invention claimed in our Patent Specification No. 1311879.

In our Patent Specification No. 1311879, we have described and claimed a fuel-injection system for an internal-combustion engine of the kind in which liquid fuel is injected through a nozzle into a flow duct through which combustion air flows to a combustion chamber of the engine. More specifically, the fuel injection system is one wherein the nozzle is continuously connected to a constant pressure source of liquid guel and is so arranged inthe said flow duct as to normally form in the duct a solid jet of fuel, a collector orifice from which the fuel reaching the orifice is drained or withdrawn to a fuel return line, being so arranged in the line of this jet as to normally intercept all the fuel in the jet. The fuel-injection system further comprises an ultrasonic vibrator associated with the nozzle and arranged when energised to cause at least the major part of the fuel leaving the nozzle to become atomised into a mist of fuel mixed with the combustion air passing through the duct, and an automatic timing-control device so controlling the energisation of the vibrator as to energise the vibrator, in each of successive cycles determined by the revolution of the engine, for a period, shorter than the cycle, whose length is variable to comply with varying fuel requirements of the engine.

We have found that the ultrasonic vibrations of the nozzle break-up the solid jet to transform it into a conically flared spray of droplets or small packages of liquid, of which only a small proportion reaches the collector orifice. The majority strike the end of the collector tube and/or other surfaces surrounding the collector orifice and are, by the impact, further comminuted to form a mist of minute droplets which is readily carried away by the flow of air. In this manner it is possible to vary the effective rate of fuel injection into the flow of combustion air in the induction pipe of an engine by arranging for the ultrasonic vibrator to be energised intermittently during a variable fraction of the length of each induction period of the engine. However, although the fuel transferred to the induced flow of combustion air by the described action is very finely distributed, it may sometimes occur that some portion of the fuel that does not reach the collector orifice forms a condensate-like layer on the surfaces surrounding the end of the collector orifice.

The present invention aims to provide an improved fuel-injection system which reduces the risk of such occurrence.

Accordingly, this invention provides a fuel-injection system for an engine comprising a fuel injection nozzle which has an orifice and which is continuously connected to a constant pressure source of liquid fuel and is so arranged in an air flow duct as to normally form in the duct a solid jet of fuel, a collector irifice from which the fuel reaching the collector orifice is drained or withdrawn to a fuel return line and which is so arranged in the line of the fuel jet as to normally intercept substantially all the fuel in the jet, an ultrasonic vibrator associated with the nozzle and arranged when energised to cause at least the major part of the fuel leaving the nozzle to become atomized into a mist of fuel mixed with air passing through the duct, and an automatic timing-control device so controlling the energisation of the

vibrator as to energise the vibrator, in each of successive cycles determined by the revolution of the engine, for a period, shorter than the cycle, whose length is variable to comply with varying fuel requirements of the engine, said collector orifice being such that the surface which surrounds it and on which any non-atomized fuel is likely to impinge, is subjected to ultrasonic vibrations (as herein defined) during the same periods in which the nozzle is subjected to such vibrations, in such manner as to cause those particles of non-atomized fuel that have not been sufficiently broken-up to be projected back into the vicinity of the nozzle, and the nozzle orifice being surrounded by a surface which vibrates with the nozzle and acts to project the non-atomised fuel particles from the collector orifice surrounding surface back to the collector orifice surrounding surface, the fuel injection system being such that the non-atomised fuel particles are thrown to and fro between the collector orifice surrounding surface and the nozzle orifice surrounding surface until the non-atomised fuel particles are completely dispersed.

Preferably, the nozzle orifice surrounding surface is comprised by the end surface of a first horn which forms part of the nozzle, the horn being extended so as to provide in alignment with it a similar oppositely directed second horn which is so connected with the first horn that the end surfaces of the two horns face each other, the second horn being provided with the collector orifice. The end surfaces of the two horns are preferably 5mm apart, although other short distances may obviously be employed. Advantageously, the second horn will be connected to the fuel return line. If desired, a second ultrasonic vibrator, energised in appropriate phase relation to the first-mentioned ultrasonic vibrator, may be provided for the second horn.

The invention will now be described solely by way of example and with reference to the accompanying drawing, in which

Figure 1 is a side elevation which shows part of a fuel injection system in accordance with the invention;

Figure 2 is a fragmentary sectional view of the inter-connected, mutually facing end portions of the horns of two transformers, drawn to a larger scale, and

Figure 3 is a section on line 3-3 of Figure 1.

Referring now to the drawing, a fuel injection nozzle 1 is secured in an air flow induction pipe 2 leading to an internal combustion engine (not shown), in such a manner as to extend across the flow of air in the pipe 2. The nozzle 1 has a vibrator body 4 and a piezoelectric transducer 3 which is attached to the outer end of the body 4. At a distance of one quarter wave-length of vibrations at the frequency of operation of the transducer 3, that is to say in a nodal zone, the body 4 is provided with a transverse bore 5 adapted to be connected to a supply of liquid fuel. At the opposite side of the nodal zone, the body 4 is constructed as an amplitude or velocity transformer terminating in a so-called horn 6. In accordance with a preferred and illustrated feature of the invention, the horn 6 is further extended beyond the anti-nodal zone 7 to continue as corresponding horn 9 of a vibrator body 8. The horn 9 is aligned with the horn 6 and extends in the opposite direction to the horn 6.

It will be readily appreciated that the vibrator body 8 will have a nodal zone at the same distance from the anti-nodal zone 7 as the nodal of the body 4, but at the opposite side of the anti-nodal zone 7. In this nodal zone, the body 8 is provided with a transverse bore 10 adapted to be connected to a line for returning the fuel which has been supplied through the inlet 5 and has not been otherwise disposed of. It will also be appreciated that the outer end surface of the body 8 will constitute another antinode, which will vibrate in a similar manner as, and in a predetermined phase relation to, the outer end surface of the body 4, even if no additional transducer is applied to the body 8.

A slot 11 extends through the greater part of the cross-section of the double horn 6, 9 and is symmetrical about the anti-nodal zone 7. The slot 11 is provided to produce two mutually facing surfaces 12 and 13. The open side of the slot 11 is preferably arranged to face downstream of the ppipe 2 and the width of the slot 11 is preferably approximately 5mm. It is to be realised however that the width of the slot may vary according to the cross-section of the horns and the depth of the slot. The bottom of the slot is preferably concave in a longitudinal section, as shown in Figure 3.

Mutually aligned bores 14 and 15 which respectively intersect the transverse bores 5 and 10, are provided in the horn-and-transformer bodies 6, 4 and 9, 8 respectively. The ends of the bores 14, 15 face each other in the surfaces 12 and 13 of the slot 11. The end of the bore 15 in the surface 13 constitutes a collector opening for a jet of liquid fuel which is formed by a nozzle orifice member 16 (Figure 2) inserted into a suitable counter bore at the end of the bore 14 in the surface 12. In the absence of vibration, this nozzle orifice member 16 will produce a jet 17 of a diameter somewhat smaller than that of the collector bore 15. When the transducer 3 is energised it applies to the nozzle 16 and to the two opposed surfaces 12 and 13, vibrations at the ultrasonic frequency of the transducer. The

amplitude of these vibrations is increased by the transformer horn 6, with the result that the solid jet 17 shown in Figure 2 is transformed into a flared spray 18 of small packages of fuel, the majority of which will not reach the collector bore 15 but will strike the surface 13 surrounding the same. By the resulting impact the greater part of each package is further dissipated into minute droplets which are carried away by the flow of air in the duct 2. Any remaining larger particles will, due to the vibration of the surface 13, be thrown back against the surface 12, where again each particle will, due to the impact, be further disintegrated. This action will be repeated as often as necessary to completely convert the injected fuel into a fine mist readily carried away by the flow of air in the induction pipe 2.

Due to the reflecting action of the concave bottom 19 of the slot 11 the mist, mixed with air from the flow in the pipe 2, will leave the slot as a cone-shaped spray 20. The concave profile of the bottom 19 acts to prevent the mist spray from spreading unduly in the longitudinal direction of the slot, thus keeping the mist particles away from the walls of the pipe 2. The narrow width of the slot 11 ensures that, even though the surfaces 12 and 13 are not exactly in the anti-modal zone of the opposed transformer horns, they are nevertheless arranged so closely to that zone as to operate with very nearly the maximum amplitude available.

As in our Patent Specification No. 1311879, the terms 'ultrasonic vibrations' and 'ultrasonic frequency' are used in this specification, unless the context otherwise requires, to refer to frequencies whose application to a jet-producing nozzle supplied with liquid will cause the jet of liquid to disintegrate into small mist-like particles. This terminology is that generally employed in the art of so-called ultrasonic fuel atomization. The frequency range in question may in practice be found to have its lower limit somewhere near the upper limit of audibility to a normal human ear, and for reasons of noise suppression it is generally preferable in practice to use frequencies high enough to ensure that they will not produce any audible sound.

The automatic timing-control device used in the fuel-injection system of the invention may be that described in our Patent Specification No. 1311879 and reference is made to Figure 1 of Patent Specification No. 1311879 which illustrates an entire fuel-injection system.

WHAT WE CLAIM IS:-

1. A fuel-injection system for an engine comprising a fuel injection nozzle which has an orifice and which is continuously connected to a constant pressure source of liquid fuel and is so arranged in an air flow duct as to normally form in the duct a solid jet of fuel, a collector orifice from which the fuel reaching the collector orifice is drained or withdrawn to a fuel return line and which is so arranged in the line of the fuel jet as to normally intercept substantially all the fuel in the jet, an ultrasonic vibrator associated with the nozzle and arranged when energised to cause at least the major part of the fuel leaving the nozzle to become atomized into a mist of fuel mixed with air passing through the duct, and an automatic timing-control device so controlling the energisation of the vibrator as to energise the vibrator, in each of successive cycles determined by the revolution of the engine, for a period, shorter than the cycle, whose length is variable to comply with varying fuel requirements of the engine, said collector orifice being such that the surface which surrounds it and on which any non-atomized fuel is likely to impinge, is subjected to ultrasonic vibrations (as herein defined) during the same periods in which the nozzle is subjected to such vibrations, in such manner as to cause those particles of non-atomized fuel that have not been sufficiently broken-up to be projected back into the vicinity of the nozzle, and the nozzle orifice being surrounded by a surface which vibrates with the nozzle and acts to project the non-atomized fuel particles from the collector orifice surrounding surface back to the collector orifice surrounding surface, the fuel-injection system being such that the non-atomized fuel particles are thrown to and fro between the collector orifice surrounding surface and the nozzle orifice surrounding surface until the non-atomized fuel particles are completely dispersed.

2. A fuel-injection system according to claim 1, in which the nozzle orifice surrounding surface is comprised by the end surface of a first horn which forms part of the nozzle, the horn being extended so as to provide, in alignment with it a similar oppositely directed second horn which is so connected with the first horn that the end surfaces of the two horns face each other, the second horn being provided with the collector orifice.

3. A fuel-injection system according to claim 2, in which the end surfaces of the two horns are 5mm apart.

4. A fuel-injection system according to claim 2 or claim 3, in which the second horn is connected to the fuel return line.

5. A fuel-injection system as claimed in claim 5 of Patent Specification No. 1311879 and modified substantially as herein described with reference to and as illustrated in the accompanying drawing.

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1432760 COMPLETE SPECIFICATION

1 SHEET This drawing is a reproduction of the Original on a reduced scale

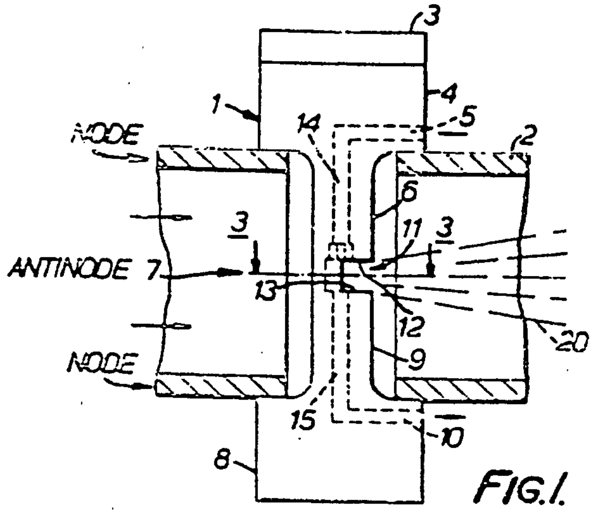

FIG.1.

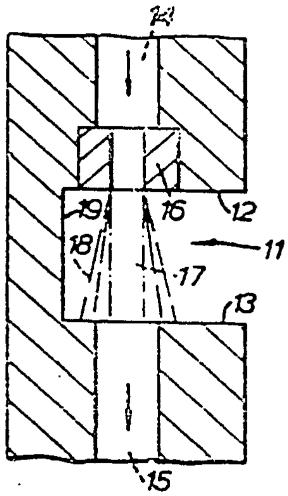

FIG.2.

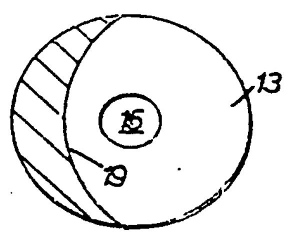

FIG.3.